Acta Orthop Scand 1991; 62 (6): 554–556

Removal torque for bone-cement and titanium screws implanted in rabbits

Per Morberg and Tomas Albrektsson

Screw-shaped implants of commercially pure titanium and polymerized methyl methacrylate were inserted into the rabbit tibia. The animals were divided into two groups, and the implants were unscrewed after 5 weeks and 9 months, respectively. After both intervals, removal torque was greatest for the titanium implants. This difference was probably due to lower biocompatibility for the plastic material.

University of Gothenburg, Biomaterials Group, Department of Handicap Research, Brunnsgatan 2, S-413 12 Gothenburg, Sweden
Tel +46-31 410919. Fax +46-31 823137
Submitted 90-10-30. Accepted 91-08-18

We compared fixation in bone of implants manufactured from cured bone cement (PMMA) and titanium.

Materials and methods

Animals and anesthesia

Nineteen 9–12-month-old, male and female, adult New Zealand White rabbits were divided into two groups, of which one group was followed for 5 weeks and the other for 9 months.

Implants

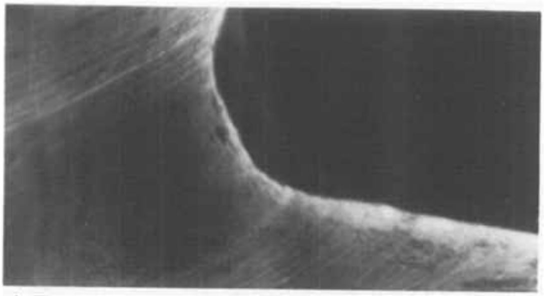
Two types of screws were used. One type was manufactured from commercially pure titanium, whereas the other was made of vacuum-mixed PMMA (Simplex®). The threads of the screws were manufactured in the same way and by the same engineer. The diameter of both screw types were 3.7 mm. The top of the implants were square to fit a specially constructed connector. Under scanning electron microscopy, the bone cement implants were observed to have a slightly rougher surface than the titanium implants (Figure 1).

Surgery

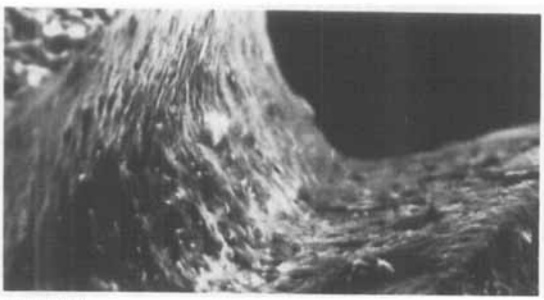
Under anesthesia an implant of titanium was inserted into one tibia, and the other tibia of the same animal received a PMMA implant. After cutting through the skin, the fasciae were sectioned separately, the cortex was penetrated with a fine drill, and the hole was gradually enlarged with wider drills using a low rotation speed.

Threading was done at a rate of 15 revolutions per minute. All the procedures were done during careful cooling to ensure minimal tissue damage. The implants were screwed down to a level where only one thread was visible above the cortical plane. After insertion of the implant, the soft tissues were sutured in separate layers. All the procedures were done under sterile conditions. After surgery, the animals were allowed full weight bearing. After 5 weeks, there were no signs of infection around the implants. One of the animals of the 5-week group was found dead in its cage after 4 weeks and was excluded.

Table 1. Removal torque (Ncm) for screw implants 5 weeks and 9 months after insertion



A. Titanium.



B. PMMA.

Figure 1. The surface of the implants, ×100.

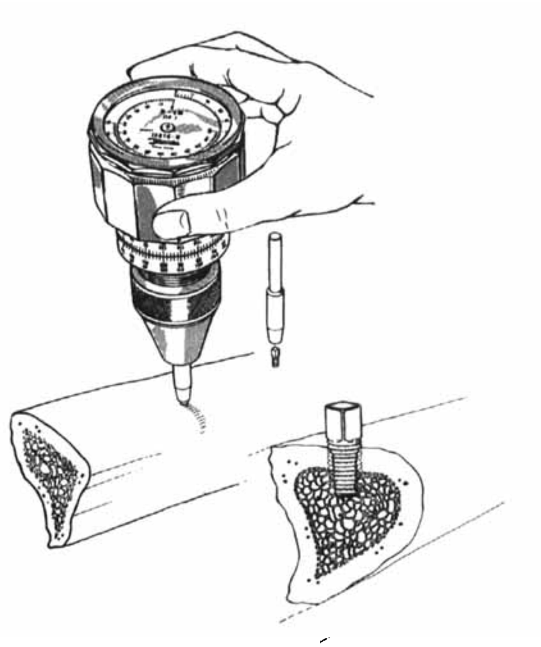


Figure 2. The removal torque screw implant in situ. The square-shaped top fits a specially constructed connector. A Tohnichi 15 BTG-N torque-gauge instrument with its connector was used to unscrew the implants.

Torque measurements

After 5 weeks and 9 months, respectively, the soft tissues were again sectioned to expose the top of the screws. All the soft tissues growing on and around the screws were removed. In the cases with bone growing up on the screw, this was removed down to the thread level. A Tohnichi 15 BTG-N torque-gauge instrument with its connector was used to unscrew the implants (Figure 2). The Wilcoxon signed rank test was used to compare the PMMA and titanium implants.

Results

In both PMMA groups, some of the screws were overgrown with soft tissue, whereas no such reaction was seen in the titanium groups. After 9 months, some hard tissue had grown up on top of the titanium screws, but not on the PMMA screws. The median removal torques were 19 and 12 Ncm (5 weeks) and 32 and 12 Ncm (9 months) in the titanium and PMMA groups, respectively (Table 1).

Discussion

Linder (1988) inserted PMMA plugs into the rabbit tibia. The plugs were covered with a thin layer of pure titanium, which was removed in certain areas. Histologic studies showed a direct bone-to-implant contact with both titanium and cement. Our data are not necessarily in controversy with those of Linder (1988), as the latter's data were not quantified and analyzed statistically. In a histologic study where bone contact with screw implants was quantified, we observed, 9 months after insertion, only some spotty bone contact with PMMA, but a 55–79 percent direct bone-to-titanium contact (Morberg and Albrektsson 1991).

The observed differences between titanium and cement implants could be explained in various ways. The surface of the PMMA implants was rougher. Carlsson et al. (1988) observed that very smooth implants needed less removal torque than did ordinary implants. Because the PMMA screws are rougher and yet needed less removal torque, this explanation is unlikely. Still, the assumed *higher surface energy* of a metal compared with a polymer (after identical sterilization etc.) could be one factor of importance for the observed results; high surface energy has been regarded as advantageous for implant take (Baier et al.

1984). However, recent studies (Carlsson et al. 1989, Wennerberg et al. 1991) have questioned the importance of high surface energy differences, presumably because energy will be lost when the implant comes in contact with the host bed.

Further, PMMA and titanium have *different moduli of elasticity*. In a quantitative study by Albrektsson (1984) where the possible effects of the elastic modulus differences between PMMA and titanium were controlled, there was, nevertheless, an impaired bone response to the PMMA-treated chambers.

Another explanation is related to the toxic monomer in the bone cement. However, the leakage of monomer from the polymerizing PMMA will decrease rapidly after onset of polymerization. For instance, only 4 hours after mixing, the monomer concentration seemed unable to cause any interfacial necrosis (Schoenfeld et al. 1979). Because the PMMA screws were not implanted until 4 weeks after polymerization, the leakage of monomer could probably be disregarded.

The remaining explanation for our findings is related to a report by Lintner (1983), who suggested that the reason for poor bone formation around bone cement is the leakage of dimetylparatoluidine (DMpT) from the PMMA. DMpT is a catalytic agent known for its high toxicity; and the substance can, 10 years after surgery, still be detected in polymerized PMMA.

We conclude that poor biocompatibility of the cement is the most probable reason for our observations.

Acknowledgements

This study has been supported by grants from the King Gustav V Jubilee Foundation, Greta and Einar Askers Foundation, Swedish Society for Medical Research, Gothenburg Medical Society, Hjalmar Svensson Foundation, and the Medical Research Council (MFR).

References

Albrektsson T. Osseous penetration rate into implants pretreated with bone cement. *Arch Orthop Trauma Surg* 1984; 102 (3): 141–7.

Baier R E, Meyer A E, Natiella J R, Natiella R R, Carter J M. Surface properties determine bioadhesive outcomes: methods and results. *J Biomed Mater Res* 1984; 18 (4): 327–55.

Carlsson L, Röstlund T, Albrektsson B, Albrektsson T. Removal torques for polished and rough titanium implants. *Int J Oral Maxillofac Implants* 1988; 3 (1): 21–4.

Carlsson L V, Albrektsson T, Berman C. Bone response to plasma cleaned titanium implants. *Int J Oral Maxillofac Implants* 1989; 4 (3): 199–204.

Linder L. The reaction of bone cement. *Acta Orthop Scand* (Suppl 227) 1988; 59: 124.

Lintner F. Die Ossificationsstörung an der Knockenzement Knochengrenze. *Acta Chir Austr* (Suppl 48) 1983; 15: 1–17.

Morberg P, Albrektsson T. Direct bone contact for rabbit screw implants of polymerized methyl methacrylate and commercially pure titanium; a short- and long-term light microscopic study. 1991 Submitted.

Schoenfeld C M, Conard G J, Lautenschlager E P. Monomer release from methacrylate bone cements during simulated in vivo polymerization. *J Biomed Mater Res* 1979; 13 (1): 135–47.

Wennerberg A, Bolind P, Albrektsson T. Glow discharge pretreated implants combined with temporary bone tissue ischemia. *Swed Dent J* 1991; 15 (2): 95–101.